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ABSTRACT

Current budgeting techniques are reviewed in relation to their application to higher education, including (1) incremental budgeting, where decisions are based primarily upon former levels of expenditures, (2) zero-based budgeting, involving the establishment and ranking of "decision packages", (3) Planning and Programming Budgeting System (PPBS), in which a systematic allocation process directs everyone toward the same goals, (4) Objectives, Strategies and Tactics (OST) that divides long-range strategies into shorter-range actions or decision packages, and (5) analytical system models, particularly goal programming, a linear mathematical modeling technique which handles multiple conflicting objectives. As a best alternative for college budgeting, the steps of goal programming are discussed including the determination of assumptions necessary for model formations, the goals for the budget period, the priority rank and weight for each goal, identification of decision variables, the formulation of system and goal constraints and of the objective function, the running of the program, analysis of the results, and the development of the budgetary implications. Finally, standard linear programming and goal programming outcomes are compared. Problems of implementation of goal programming for Yavapai College, Arizona, in the 1977/78 budgeting process are described. (RT)

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A DECISION THEORY APPROACH TO COLLEGE RESOURCE ALLOCATION

PRESENTED TO 1978 CONFERENCE
OF CALIFORNIA ASSOCIATION
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INTRODUCTION

Institutions of higher education are facing serious financial crises and are having to make critical decisions regarding specific programs. At some colleges, entire programs are being cut in order to balance the budget. Because educational costs are rising more rapidly than costs of many other agencies vying for tax dollars, significant attention is being focused on these costs at federal, state and local levels.

The present state of the economy certainly is a strong contributing factor to the financial dilemma facing institutions of higher education. Because of a steady rate of inflation, the buying power of the dollar has been consistantly eroded. The taxpayer is beginning to rebel over high tax rates and is taking a keen interest in any proposal to increase the rate. In addition, budgets are being formulated with very little "fat" because of the shortage of revenues and because of the increased scrutinizing from administrators, state and local boards, legislators and taxpayers. This greatly reduces the built-in contingency funds inherent in budgets of previous years.

In many parts of the country, enrollment at these institutions is growing at a much decreased rate over comparable periods in the 1960's. It is anticipated that nationally enrollment will level in the late 1970's and will actually decrease in the 1980's.

Increasing productivity does not appear to be the answer to the financial problems of educational institutions in general. Much of

the cost of an institution is for personal services. In the Arizona Community College System, for example, personal services represent approximately 75% of the total operational budget (18). It is very difficult then to expect to significantly improve overall productivity of an institution unless the normal load of 14-16 hours per semester of the teaching faculty is increased. This does not appear likely.

Sims (16:1) has stated that "The tendency is for administrators to expound on financial crises; the legislators to weigh requests of the multitude of constituents; and for state boards to develop formulae and validating rationale. The question is recurring and should be faced in a systematic manner." Officials at these levels are starting to ask detailed questions before allocating financial resources to higher education. For example, they may ask:

a) What are the objectives of the institution, department, program or course?

b) How do you measure whether objectives have been met or how well they have been met?

c) How should resources be allocated?

d) How are priorities established for programs?

e) Who would make decisions on the establishment of programs and whether they should be enhanced, reduced or terminated?

The purpose of this paper is to discuss question (c) above which asks "How should resources be allocated?" Several resource allocation methods will be discussed which are capable of handling multiple criteria. It is the intent of the author to show the advantages of using computerized modeling techniques in decision making as related to the resource allocation process.

BUDGETING TECHNIQUES

Budgeting techniques in use today depend heavily on the type of management philosophy being used within the institution. Several budgeting techniques currently in use within educational institutions will now be discussed. Although each technique is defined separately, they are not mutually exclusive and may exist in many combinations.

Two basic or primary budgeting techniques used today are incremental budgeting and zero-base budgeting. In incremental budgeting, allocation decisions are based primarily upon the basis of prior levels of expenditures. Decisions then involve a deviation or change from the prior years level of effort. Zero-base budgeting involves the review of all programs and expenditures on an annual basis from the ground up.

It has been stated by Harnett (9:13) that "Incremental budgeting is an underlying cause of New York City's fiscal crisis as it is the crisis in many cities. Few cities seem to have procedures for altering a budgetary course once launched. Consequently, programs often become entrenched, resistant to productivity analysis or to whether they accomplish goals." After many years, the organization can acquire a significant amount of crabgrass.

Zero-base budgeting as indicated in Pyhrr (15), involves two basic steps. The first is to develop "decision packages." This involves analyzing and completely defining each continuing or new discrete activity and grouping it into one or more packages for funding consideration. The second step involves ranking the "decision packages" in order of priority based upon cost/benefit analyses and/or subjective evaluations. Once the packages are ranked, resources can be allocated to the appropriate level.

The zero-base budgeting technique is certainly the most logical procedure to be used for budgeting; however, it does take a significant amount of effort and may be prohibitive to accomplish on an annual basis.

It is the opinion of the writer that both techniques are appropriate in a college or university budgeting environment. Unlike many industrial environments, work loads in most functional areas change gradually and do not vary dramatically from year to year. For this reason an incremental approach could be used to determine the operational budget for a period of one to three years and the zero-base technique applied at the end of that period. In this way, a functional area that starts to drift off track could be readjusted every two to four years. In general, capital funds should be allocated on an annual basis because in most cases past expenditures do not reflect current or future needs. Therefore, a zero-base budgeting approach should be applied to capital expenditures every year.

The 1973 SMU Institute of Technology Report (17) defines six other budgeting techniques in use today. They are (1) Every Tub on Its Own Bottom, (2) King's Decree, (3) Squeaky Wheel Gets Grease, (4) Formula, (5) Planning and Programming Budgeting System (PPBS) and (6) Objectives, Strategies and Tactics. Each of these will now be defined.

The "Every Tub on Its Own Bottom" technique involves the establishment of several independent, self-supporting revenue/expense centers. Each center develops its own revenue sources and makes all the primary decisions on how the money is spent.

The "King's Decree" approach is analogous to the autocratic form of management. All revenue and expenditure decisions are made centrally and are made with or without consulting with other members of the staff.

In the "Squeaky Wheel Gets the Grease" approach, allocation is made by giving preference to those expense centers that make the most noise. Universal consideration of top level goals and objectives doesn't occur in this case. This technique is found where systematic procedures do not exist and is accompanied by bureaucratic infighting, politicking, extravagant claims and misleading statistics.

The "Formula" allocation method uses a formula which is based upon a unit of production such as student credit hours (SCH) or full time student equivalents (FTSE). This method has been used primarily by state agencies in allocating financial resources to community college districts. In addition, this method is helpful in making "what if" studies and as such is a better tool for decision making rather than allocation of resources.

PPBS is a technique which uses a scientific approach to resource allocation. The seven basic steps in the process are:

1. Identification of top level goal(s)
2. Definition of objectives
3. Definition of programs necessary to meet objectives
4. Multi year analysis and planning
5. Consideration of alternative solutions
6. Evaluation of alternatives and selection of "best solution"
7. Replanning

This procedure facilitates a systematic allocation process and insures that everyone is directed toward the same goals and objectives. However, PPBS has not succeeded very well in the educational field to date for the following reasons as indicated in (17:7):

1. An effective management Information System is required and very few educational institutions meet this requirement.
2. More priority or focus has been given in the past to the activities to be performed rather than the overall goals and objectives of the institution.
3. More emphasis has been placed upon the development of mathematical models rather than on the anticipated results.
4. A greater stress has been placed on the mechanics and formalism of the process rather than the spirit and concept of the process.

In spite of these problems, PPBS appears to be one of the best alternatives available for budgeting in educational institutions. It provides a systematic framework for resource allocation considering the institution's goals and objectives which must be clearly defined if the process is to be meaningful.

Objectives, Strategies and Tactics (OST) is a method for developing the strategic budget. As indicated previously, the items included in the Strategic Budget are required for long range goal optimization but are discretionary as far as the current operating budget is concerned. This method was developed by Patrick Haggerty when he was President of Texas Instruments Incorporated. Again, the technique is based upon well-defined objectives which in this case are quantitative statements of intentions and purposes. Strategies are defined as long range actions which are implemented for the purpose of achieving these objectives. The strategies are subdivided into shorter range actions each of which supports the particular strategy being considered. The tactics are grouped into

stand alone decision packages which are similar to those developed in zero-base budgeting. These packages are then prioritized and selection accomplished in a manner similar to zero-base budgeting. One of the most difficult decisions an administration has is the determination of how much of an overall revenue pool should be allocated to the current operating budget for immediate use and how much should be invested for the future in the strategic budget.

ANALYTICAL MODELS FOR PLANNING AND BUDGETING

Weathersby and Weinstein (19) performed an extensive study on university planning models and categorized them by:

1. Function or purpose of model
2. Theoretical foundation for the particular formulation
3. The mathematical techniques used
4. Subjects of the model
5. Sources of data
6. Uses of model
7. Operational Status

Mathematical models can be subdivided into derivation models, projection models and allocation models. Derivation models are designed to derive basic measures of performance such as cost per student credit hour, student/teacher ratios, etc. Projection models continue current operating parameters and project factors into the future. Models which address the problem of allocating a fixed amount of resources among various alternatives are defined as allocation models. This is the type of model which is explored in this document.

Mathematical techniques or methods used in current allocation models can be classified as either optimizing or non-optimizing depending on whether an objective function is included. Non-optimizing models or simulation models as they are alternatively referred to, are the most popular in use today in educational institution planning and decision making activities. These models attempt to relate input with output through the use of mathematical formulas. They are very powerful in playing what-if games which is the prediction of the change in a particular output due to either a change in input or a change in internal policy or constraints. These models can be deterministic or probabalistic depending on whether uncertainty is or is not included. These models provide no ability to determine an optimum allocation of resources evaluated.

Optimizing models as listed in (19) are restricted to the following mathematical programming techniques:

1. Linear programming
2. Non-linear programming
3. Dynamic programming
4. Optimal Control Theory

The report indicates that the use of optimizing models in the allocation of financial resources is almost non-existent.

Geoffrion et al. (7) indicate that one of the most serious difficulties in the application of mathematical programming techniques to the problems of post secondary education is the presence of multiple and sometimes conflicting criteria and objectives. The report indicates that very little has been done to develop techniques necessary to cope

with this problem. The report discusses an interactive mathematical model developed to solve multicriteria problems by using the Frank-Wolfe method. The method which is quite complex is applied to the development of aggregate annual operating plans for the Department of Management at UCLA.

Another technique which has increased in popularity over the past few years is that of goal programming. Goal Programming is a linear mathematical modeling technique which handles multiple conflicting objectives composed of linear prioritized functions. In order to trace the development of goal programming, it is necessary to briefly review the history of mathematical programming.

As indicated by Lee (12), the development of mathematical problems had its origins in the theories of linear and non-linear equations and inequalities; however, George B. Dantzig is accepted as the "father of linear programming." His major work was conducted in the early 1940's while he was solving logistics problems for the United States Air Force. After 1948, several others worked with Dantzig in refining linear programming techniques and investigating the use of these techniques in industrial problem solving. Charnes and Cooper (1) studied many different applications in the industrial area. They also developed the basic concepts of goal programming (2) and discussed in (1) the concept that whether goals are attainable or not, an objective may be stated in which optimization gives a result which comes as close as possible to the indicated goals.

Ijiri (10) extended the basic goal programming concepts developed by Charnes and Cooper and presented the definition of "preemptive priority factors" to handle multiple goals according to their relative

importance and assigned weights to goals of the same priority level. He also formulated the generalized inverse approach as the solution algorithm. Ijiri developed goal programming as a distinct mathematical programming technique and discussed its possible applications to accounting and managerial control problems.

As indicated previously, Charnes and Cooper first applied goal programming techniques. Two such applications were presented in the year 1968 (3, 4 & 5) - the areas of advertising - media and manpower planning problems. B. Contini (6) studied the use of goal programming methods under conditions of uncertainty and provided the mathematical feasibility for the stochastic approach to goal programming.
V. Jaaskelainen presented a comprehensive study (11) which used goal programming to solve aggregate production planning problems. Multiple goals involving production, demand variations, inventory control and subcontracting were considered.

Sang Lee (12, 13 & 14) has made significant contributions in further developing the goal programming process and studying additional applications. Examples of areas studied are:

a) Academic planning

b) Financial planning

c) Economic planning

d) Hospital administration

Lee (12) presents a computer program developed by V. Jaaskelainen and himself for solving goal programming problems.

The use of goal programming techniques, however, has only scratched the surface of potential applications. Lee (12:18) states "Since goal programming is a relatively new technique, its true potential is yet to

be determined. However, it appears that the potential applicability of goal programming may be as wide as that of linear programming. Goal programming has a great deal of flexibility that is lacking in linear programming. Furthermore, the approach of multiple-goal attainment according to their priorities is readily suitable to most management decision problems."

GOAL PROGRAMMING APPROACH

General

The "traditional" applications of linear programming (LP) have been inventory control, production, scheduling, process mixing, and transportation problems. In these areas as well as others, LP has been an extremely powerful tool. Linear programming has one important requirement which is that the objective function be unidimensional. This means that there can be only one primary goal such as to minimize cost or maximize profit. If a problem has multiple goals or objectives, it is necessary to reduce each to a common measure of effectiveness. In an industrial application this process becomes somewhat feasible although quite tedious. However, in the application proposed in this document, the typical linear programming approach is not useful. This results from the fact that resource allocation in educational institutions involves multiple goals which are competitive, often conflicting and of varying priorities.

Goal programming circumvents the problem associated with linear programming as discussed above. In goal programming, the same basic algorithms are used, however, the problem is formulated in a different manner.

In linear programming, an objective function is optimized subject to a given set of constraints. Each constraint has an associated "slack" variable which is basically a dummy variable. These variables indicate the degree to which the constrained resource is used in the final solution. When the slack is zero, all of the constrained resource has been utilized.

Instead of attempting to maximize or minimize the goal criteria directly as in linear programming, the objective function contains only the slack variables. The "goals" are formulated as constraint equations with both real variables and positive and negative slack variables. The goal is stated numerically on the right hand side of the constraint equation and the deviation from the goal is represented by the plus and minus slack variables. These slack variables are included in the objective function with either a positive or zero weight which is dependent on the results of a goal analysis.

The goal programming model then minimizes the deviations between actual results and desired goals. If all deviations are reduced to zero, this indicates that all goals are achieved.

Gibbs (8) has expressed the general goal program model mathematically as,

$$\text{minimize } Z = \sum_{i=1}^{M} (P_{i1}\ d_{i1} + P_{i2}\ d_{i2})$$

Subject to:

$$A_{11} X_1 + A_{12} X_2 + \ldots\ldots + A_{1n} X_n - d_{11} + d_{12} = B_1$$

$$A_{21} X_2 + A_{22} X_2 + \ldots\ldots + A_{2n} X_n - d_{21} + d_{22} = B_2$$

$$\vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots$$

$$A_{m1} X_m + A_{m2} X_2 + \ldots\ldots + A_{mn} X_n - d_{m1} + d_{m2} = B_m$$

$$X_j \, , \, d_{i1} \, , \quad d_{i2} > 0 \quad \text{for all } i \, , \, j$$

Where:

B_i are quantitative measures of the m goals.

X_j are n variables associated with the m goals and are the input or output variables.

A_{ij} are the coefficients of the n variables which relate the input variables with the n goals.

d_{i1} is the amount of overachievement in goal i.

d_{i2} is the amount of underachievement in goal i.

P_{i1} is the priority weight assigned to overachievement of goal i.

P_{i2} is the priority weight assigned to underachievement of goal i.

Lee and Nicely (13) define two types of constraints in the goal programming mode which are goal constraints and "fact-of-life" or system constraints. The system constraints are established in the same manner as the goal constraints, however, the slack variables are not included in the objective function.

As indicated by Gibbs (8), two approaches can be used to solve the goal programming problem. The first approach is to determine an ordinal priority ranking and then a weight is assigned in order to establish a cardinal ranking. This priority weight is P_{i1} or P_{i2} in the above equations. The second approach is to stop with the ordinal ranking and apply the techniques developed by Lee (12). The cardinal weighting approach can utilize the standard linear programming package available on most medium to large scale computers. The second approach or ordinal ranking method requires a special program which is presented in Lee (12). Both techniques will be used on the same data and the results compared. The cardinal weighting approach as indicated by Gibbs (8:39) "can provide a finer tuned result." In Lee's approach (12) the goal program treats multiple, conflicting goals according to the importance assigned to them in such a way that the low order goals are considered only after the higher order goals are satisfied or have reached the point beyond which no further improvements are possible. If overachievement of the goal is acceptable, d_{i1} can be eliminated from the objective function. If underachievement is acceptable, d_{i2} can be eliminated from the objective function. However, if the goal must be achieved exactly, d_{i1} and d_{i2} should be left out of the objective function. Lee (12:27) also specifies that in the ordinal priority technique the following relationship must hold:

"$P_j >>> n\, P_{j+1}$ $(j = 1, 2, \ldots, K-1)$ which implies that the multiplication of n, however large it may be, cannot make P_{j+1} greater than or equal to P_j."

One undesirable feature of the goal programming approach is that all slack or deviational variables must be specified during the model

formulation process instead of allowing the LP program to do it automatically since they must be specified in the objective function. However, this is a minor inconvenience when the overall power of this approach is considered.

Procedure

The following steps are recommended for the development of a goal programming model:

1. Determine assumptions necessary for model formulation.
2. Determine goals for the budget period.
3. Establish priority rank for each goal.
4. Determine priority weight or cardinal rank for each goal (if required).
5. Identify decision variables.
6. Formulate system and goal constraints.
7. Formulate the objective function.
8. Run program.
9. Analyze the results and develop implications.

As indicated by Gibbs (8), the most significant phase in the development of the model is goal analysis. It represents the most important and the most difficult phase in the development of the model. In preparation for step 7 above, it is necessary to determine for each goal whether it is satisfactory or unsatisfactory for overachievement or underachievement to take place or whether attainment must be exact. This then determines which deviational variables are included in the objective function.

Example of Cardinal Ranking Approach

Assumptions

1. The decision making body prefers to determine the optimum allocation of resources for a specified tax rate.
2. All revenue sources except district tax levies are constant from previous to next budget year.
3. Overachievement is satisfactory for all goal slack variables.
4. $300,000 of revenue is to be allocated for additional expenditures.

Goal Formulation

The goals listed in Table 1 are assumed for this example. The goals are listed from the most important to the least important along with the assumed weight and cost.

Identification of Decision Variables

In order to develop a goal programming model to achieve the above goals, the following decision variables shall be studied:

X_1 = Allocation for new personnel

X_2 = Allocation for salary increases

X_3 = Allocation for physical plant maintenance and repair

X_4 = Allocation for parking lot repair

X_5 = Allocation for capital expansion

Formulation of System and Goal Constraints

In the following equations, the variables with odd numbered subscripts greater than 5 are the "underachievement" deviational variables while those variables with even numbered subscripts greater

Table 1

Goals, Weights and Costs for the Goal Programming, Cardinal Ranking Example

GOAL	WEIGHT	COST ($)
1. Repair mandatory physical plant deficiencies plus perform preventative maintenance on all equipment.	.63	15,000
2. Repair mandatory physical plant deficiencies plus perform some preventative maintenance.	.56	12,000
3. Repair mandatory and high priority physical plant deficiencies.	.49	10,000
4. Hire 15 new instructors plus five support personnel.	.45	210,000
5. Implement step salary increase plus modify the base resulting in an overall increase equal to the present change in the consumer price index over the past year.	.44	126,000
6. Fully repair both North and South parking lots.	.43	60,000
7. Hire 10 new instructors plus 3 new support personnel.	.37	136,000
8. Implement step salary increase plus increase base equal to the percentage change in the consumer price index for the past year.	.35	216,000
9. Perform mandatory repairs on the physical plant.	.34	5,000
10. Fully repair the South parking lot.	.33	30,000
11. Allocate major funding for capital expansion.	.32	27,000
12. Allocate significant funding for capital expansion.	.28	18,000
13. Hire 5 new instructors.	.25	50,000
14. Perform minimal repair by fixing holes in both parking lots.	.24	15,000
15. Allocate modest funds for capital expansion.	.20	9,000
16. Implement salary schedule - step only no change in base.	.19	90,000
17. Defer repairs to parking lot to a future budget period.	.15	0
18. Do not hire any additional personnel.	.06	0
19. No capital allocation.	.04	0

than 7 are the "overachievement" deviational variables. In the system constraint equation, overachievement is not possible and hence the variable associated with overachievement is omitted. In the case of the goal constraints, both positive and negative deviations are acceptable and hence the appropriate variables are included along with the decision variable being considered.

System Constraint

The overall amount of money to be expended is to be limited to \$300,000. Therefore, $X_1 + X_2 + X_3 + X_4 + X_5 + X_{45} = 300,000$

Goal Constraints

1. P_1 GOAL (Highest priority)

   $X_3 + X_7 - X_8 = 15,000$

2. P_2 GOAL

   $X_3 + X_9 - X_{10} = 12,000$

3. P_3 GOAL

   $X_3 + X_{11} - X_{12} = 10,000$

4. P_4 GOAL

   $X_1 + X_{13} - X_{14} = 210,000$

5. P_5 GOAL

   $X_2 + X_{15} - X_{16} = 126,000$

6. P_6 GOAL

   $X_4 + X_{17} - X_{18} = 60,000$

7. P_7 GOAL

   $X_1 + X_{19} - X_{20} = 136,000$

8. P_8 GOAL

$X_2 + X_{21} - X_{22} = 216,000$

9. P_9 GOAL

$X_3 + X_{23} - X_{24} = 5,000$

10. P_{10} GOAL

$X_4 + X_{25} - X_{26} = 30,000$

11. P_{11} GOAL

$X_5 + X_{27} - X_{28} = 27,000$

12. P_{12} GOAL

$X_5 + X_{29} - X_{30} = 18,000$

13. P_{13} GOAL

$X_1 + X_{31} - X_{32} = 50,000$

14. P_{14} GOAL

$X_4 + X_{33} - X_{34} = 15,000$

15. P_{15} GOAL

$X_5 + X_{35} - X_{36} = 9,000$

16. P_{16} GOAL

$X_2 + X_{37} - X_{38} = 90,000$

17. P_{17} GOAL

$X_4 + X_{39} - X_{40} = 0$

18. P_{18} GOAL

$X_1 + X_{41} - X_{42} = 0$

19. P_{19} GOAL

$X_5 + X_{43} - X_{44} = 0$

Formulation of Objective Function

The objective function of the goal program is developed so as to minimize the slack or deviational variables. The appropriate weights are assigned to the deviational variables. Since it was assumed that overachievement was satisfactory, those deviational variables with a negative coefficient (d_{i1}) are deleted from the objective function. The objective function then becomes,

$$\begin{aligned} \text{minimize } Z = {} & .63 X_7 + .56 X_9 + .49 X_{11} + .46 X_{13} \\ & + .44 X_{15} + .43 X_{17} + .37 X_{19} + .35 X_{21} \\ & + .34 X_{23} + .33 X_{25} + .32 X_{27} + .28 X_{29} \\ & + .25 X_{31} + .24 X_{33} + .20 X_{35} + .19 X_{37} \\ & + .15 X_{39} + .06 X_{41} + .04 X_{43} \end{aligned}$$

Running of Program

The problem was set-up for running on the UNIVAC 1110 at Arizona State University using the FMPS Linear Programming Package. The desired results are given in Table 2. As indicated, the total expenditures are $300,000 which is the amount imposed by the system constraint requirement.

Example of Ordinal Ranking Approach

Introduction

As indicated previously, the basic difference between the cardinal and ordinal ranking approaches is in the importance or weight applied to each goal. In the previous example, the weight played an important

Table 2

Goal Programming Cardinal Example
Final Optimized Output

VARIABLE	DESCRIPTION	AMOUNT ($)
X_1	New Personnel	210,000
X_2	Salary increases	36,000
X_3	Physical plant maintenance and repair	12,000
X_4	Parking lot repair	15,000
X_5	Capital expansion	27,000
	TOTAL EXPENDITURES	300,000

part in the objective function since a standard linear programming package was used. This example will utilize a special program developed by S. Lee (12). Since Lee's version was designed for a maximum of ten priorities, it was necessary to modify it to accommodate twenty priorities. This was done by modifying the dimension statements.

After the program was modified for use with up to 20 priority levels, it was validated by using the input given in a sample problem in Lee (12). The results were identical to those given in the sample problem.

Since this example is identical to the previous example except for the goal weights, the assumptions, goal formulation and decision variables are the same.

Formulation of System and Goal Constraints

Another difference between the standard linear programming approach and the ordinal approach lies in the definition of the deviation variables. The deviational variables are defined as d_i^- and d_i^+ where d_i^- represents the amount of underachivement and d_i^+ represents the amount of overachievement.

Lee and Bird (14) define the goal programming model as:

$$\text{"minimize } \sum_{i=1}^{m} (d_i^+ + d_i^-)$$

$$\text{Subject to } Ax - Id^+ + Id^- = b$$

$$X, d^+, d^- \geq 0$$

Where m goals are expressed by an m component column vector b ($b_1, b_2, \ldots b_m$), A is an m x n matrix which expresses the relationship between goals and subgoals, x represents variables involved in the subgoals ($X_1, X_2, \ldots, X_n$), d^+ and d^- are m- component vectors for the variables representing deviations from goals, and I is an identity matrix in m dimensions."

System Constraint

The total expenditures are limited to $300,000 or

$$X_1 + X_2 + X_3 + X_4 + X_5 + d_1^- = 300,000.$$

Goal Constraints

1. P_1 GOAL (Highest priority)

   $$X_3 + d_2^- - d_2^+ = 15,000$$

2. P_2 GOAL

   $$X_3 + d_3^- - d_3^+ = 12,000$$

3. P_3 GOAL

   $$X_3 + d_4^- - d_4^+ = 10,000$$

4. P_4 GOAL

   $$X_1 + d_5^- - d_5^+ = 210,000$$

5. P_5 GOAL

   $$X_2 + d_6^- - d_6^+ = 126,000$$

6. P_6 GOAL

   $$X_4 + d_7^- - d_7^+ = 60,000$$

7. P_7 GOAL

   $$X_1 + d_8^- - d_8^+ = 136,000$$

8. P_8 GOAL

$$X_2 + d_9^- - d_9^+ = 216{,}000$$

9. P_9 GOAL

$$X_3 + d_{10}^- - d_{10}^+ = 5{,}000$$

10. P_{10} GOAL

$$X_4 + d_{11}^- - d_{11}^+ = 30{,}000$$

11. P_{11} GOAL

$$X_5 + d_{12}^- - d_{12}^+ = 27{,}000$$

12. P_{12} GOAL

$$X_5 + d_{13}^- - d_{13}^+ = 18{,}000$$

13. P_{13} GOAL

$$X_5 + d_{14}^- - d_{14}^+ = 50{,}000$$

14. P_{14} GOAL

$$X_4 + d_{15}^- - d_{15}^+ = 15{,}000$$

15. P_{15} GOAL

$$X_5 + d_{16}^- - d_{16}^+ = 9{,}000$$

16. P_{16} GOAL

$$X_2 + d_{17}^- - d_{17}^+ = 90{,}000$$

17. P_{17} GOAL

$$X_4 + d_{18}^- - d_{18}^+ = 0$$

18. P_{18} GOAL

$$X_1 + d_{19}^- - d_{19}^+ = 0$$

19. P_{19} GOAL

$$X_5 + d_{20}^- - d_{20}^+ = 0$$

Formulation of Objective Function

The formulation of the objective function for the ordinal example is simpler than the cardinal case in that specific weights for each priority level are not required. In this example, it will again be assumed that overachievement of the goals is satisfactory and hence the d_i^+ deviational variables are excluded from the objective function. Using these criteria, the objective function becomes,

$$\text{MINIMIZE } Z = P_1 d_2^- + P_2 d_3^- + P_3 d_4^- + P_4 d_5^- + P_5 d_6^-$$

$$+ P_6 d_7^- + P_7 d_8^- + P_8 d_9^- + P_9 d_{10}^- + P_{10} d_{11}^-$$

$$+ P_{11} d_{12}^- + P_{12} d_{13}^- + P_{13} d_{14}^- + P_{14} d_{15}^- + P_{15} d_{16}^-$$

$$+ P_{16} d_{17}^- + P_{17} d_{18}^- + P_{18} d_{19}^- + P_{19} d_{20}^-$$

Running of Program

The program which was developed by S. Lee (12) was adapted for the DEC System 10 at Yavapai College. The results are indicated in Table 3.

Application of Goal Programming-Ordinal Model

In applying an objective resource allocation technique such as the Goal Programming methods, many types of problems can be encountered. There is a great need for very detailed and complete procedural specifications and for orientation and training at all levels in the organization. Some problems encountered at Yavapai College during the application of such a process and the procedural specifications which resulted will now be discussed.

Table 3

VARIABLE	VALUE ($)
X_1	210,000
X_2	75,000
X_3	15,000
X_4	0
X_5	0
TOTAL	$300,000

Two basic changes were made to the Yavapai College 1977/78 budget development process. First, participation in the process was significantly increased by the formation of a District-Wide Budget Advisory Committee (BAC) consisting of Deans, Division Chairpersons, students and classified personnel. This group was formed to provide college-wide input to the Budget Development Committee (BDC) consisting of the President, Deans and the Faculty Association President. The second change was the use of the goal programming-ordinal allocation technique which moved the decision making from a purely subjective to a more objective process.

The first problem encountered dealt with the Board of Governors and their management style. The Board is the ultimate decision making body, however, they prefer not to give initial guidelines and constraints to the college administrators, and hence the first pass budget and resulting tax rate was determined entirely within the college structure. The Board feels more comfortable in a responsive mode rather than operating in a planned objective allocation process. This is partially due to the fact that most of them have full-time jobs and can only devote a few hours per month to the college administrative process. Secondly, they were not oriented and trained in the goal programming process prior to the development on the first pass budget.

The second problem existed temporarily at the Presidential level. He found it difficult initially to adjust to the participatory management model and was never certain as to when to make his thinking known and to what extent. However, the President did assist in the establishment of the college goals and objectives and assumed the role as Chairman of the Budget Development Committee.

The Deans had great difficulty adjusting to the process because of the difference in budgeting philosophy. Instead of each Dean dealing directly with the President to develop the budget for his area, the allocation process became a centralized approach with the actual dollar allocation being automatic once priorities had been established for the budget requests. The Deans generally felt a loss of autonomy in the development of their own budgets. The process was also an unknown and they had great doubts as to whether the process would actually work. However, the President gave significant support to the Dean of Business Services who had the basic responsibility for developing and implementing an objective resource allocation process.

The 1977/1978 Yavapai College Budget was given interim approval at the March 12, 1977, Board of Governors meeting and is basically the same budget which was developed by the BAC and BDC committees using the S. Lee (12) Goal Programming model. The greatest problem existed in the area of salary increases as this is a highly emotional area. However, after much discussion, the Board approved a 5.7% increase as compared to the 6.0% recommended by the administration.

RECOMMENDED RESOURCE ALLOCATION MODEL

Of the two goal programming techniques discussed, the ordinal approach is recommended for use in the higher education environment. Although Gibbs (8) indicates that the cardinal approach gives "finer tuned" results, there is a basic problem with this approach. The assignment of meaningful weights to the goals becomes quite difficult. This is an area where significant research is required in order to improve on the techniques in use today. Unless the decision maker can

accurately quantify the relationships of the goals, there is some question as to the accuracy of the solution since the output is only as good as the input. The ordinal approach is also easier to use, especially when the allocation models become more complex.

A comparison of the results of the use of the standard FMPS Package with the Goal Programming Program developed by Lee is shown in Table 4. As can be seen, the Standard Linear Programming Package allocated some resources to all five variables while the Goal Programming Package (Lee) stopped after the first three variables. The basic difference in the two techniques is in the priority structure. The Lee model must optimize a higher priority goal before moving on to the next goal. The standard linear programming model does not make this assumption and uses the numerical value of the weight of a particular goal in optimizing the allocation process.

The Lee (ordinal) resource allocation technique is recommended for use by educational institutions since it requires only that goals be prioritized and hence it is unnecessary to establish a weight for each goal. A well-defined procedure for assigning a numerical weight for each goal has not been found by the author.

An overall conclusion of the study is that a decision theory approach is beneficial to the solution of resource allocation problems. In particular, the goal programming approach has tremendous potential in this area and could become as widely used as standard linear programming techniques are used today. Budget building processes can be transformed from a purely emotional area into one in which logical processes involving prioritized goals and objectives prevail.

Table 4

Goal Programming Results Comparison

VARIABLE	ALLOCATED RESOURCES ($)	
	STD. LP PACKAGE (CARDINAL)	GOAL PROGRAMMING (ORDINAL)
X_1	210,000	210,000
X_2	36,000	75,000
X_3	12,000	15,000
X_4	15,000	0
X_5	27,000	0

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